# PROCEEDINGS

OF

# THE ROYAL SOCIETY.

1836. No. 25.

## April 21, 1836.

RODERICK IMPEY MURCHISON, Esq., Vice-President, in the Chair.

A paper was read, entitled "Additional Observations on Voltaic Combinations." In a letter addressed to Michael Faraday, Esq., D.C.L., F.R.S. Fullerian Professor of Chemistry in the Royal Institution, &c. By J. Frederick Daniell, Esq., F.R.S., Professor of Chemistry in King's College, London.

The author has found that the constant battery, of which he described the construction in a former communication to the Royal Society, might be rendered not only perfectly steady in its action, but also very powerful; as well as extremely efficacious and convenient for all the purposes to which the common voltaic battery is usually applied. With this view he places the cells which form the battery in two parallel rows, consisting of ten cells in each row, on a long table, with their siphon-tubes arranged opposite to each other, and hanging over a small gutter, placed between the rows, in order to carry off the refuse solution when it is necessary to change the acid. Having observed that the uniformity of action may be completely maintained by the occasional addition of a small quantity of acid, he is able to dispense with the cumbrous addition of the dripping funnel; an arrangement which admits with facility of any combination of the plates which may be desired.

## April 28, 1836.

DAVIES GILBERT, Esq., Vice-President, in the Chair.

Captain John James Chapman, R.A., was elected a Fellow of the Society.

On certain parts of the Theory of Railways; with an investigation of the formulæ necessary for the determination of the resistances to the motion of carriages upon them, and of the power necessary to work them. By the Rev. Dionysius Lardner, LL.D., F.R.S.

The author observes, in his prefatory remarks, that an extensive and interesting field of mathematical investigation has been recently opened in the mechanical circumstances relative to the motion of heavy bodies on railways; and having collected a body of experiments and observations sufficient to form the basis of a theory, he purposes, in the present paper, to lay before the Society a series of mathematical formulæ, embodying the most general expressions for the phenomena of the motion of carriages on these roads.

The author begins by investigating the analytical formulæ for the traction of trains over a level line which is perfectly straight, and finds, first, the distance and time within which, with a given amount of tractive power, the requisite speed may be obtained at starting; and also the point where the tractive power must be suspended, previous to coming to rest. The excess of tractive power necessary to get up the requisite speed is shown to be equal to the saving of tractive power previous to a stoppage; and formulæ are given for the determination of the time lost under any given conditions at each stop.

The motion of trains in ascending inclined planes which are straight, is next considered; and formulæ are given combining the effects of friction and gravity, in opposition to the tractive force. The circumstances which affect every change of speed, and the excess of tractive force necessary, in such cases, to maintain the requisite speed, are determined; as well as the other circumstances already stated with respect to level planes.

The friction of trains upon descending planes is next investigated; and an important distinction is shown to exist between two classes of planes; viz., those whose acclivities are inferior to the angle of repose, and those of more steep acclivities. A remarkable relation is shown to exist between the tractive forces in ascending and descending the first class of planes. For descending planes of greater acclivity than the angle of repose, the use of breaks becomes essentially requisite. The effect of these contrivances is investigated, as well as the motion of trains on the accidental failure of breaks.

In any attempts which have been hitherto made to obtain the actual velocities acquired by trains of carriages or waggons under these circumstances, an error has been committed which invalidates the precision of the results; the carriages having been treated as sledges moving down an inclined plane. The author has here given the analytical formulæ by which the effect of the rotatory motion of the wheels may be brought into computation; this effect, depending obviously on the amount of inertia of the wheels, and on the proportion which their weight bears to the weight of the waggon.

The properties investigated in this first division of the paper, are strictly those which depend on the longitudinal section of the line, presumed to be straight in every part of its direction. There is, however, another class of important resistances which depend on the ground-plan of the road, and these the author next proceeds to determine.

The author then gives the analytical formulæ which express the resistance arising,—*first*, from the inequality of the spaces over which the wheels, fixed on the same axle, simultaneously move; *secondly*, from the effort of the flanges of the wheels to change the direction of the train; and *thirdly*, from the centrifugal force pressing the flange against the side of the rail. He also gives the formulæ necessary to determine, in each case, the actual amount of pressure produced by a given velocity and a given load, and investigates the extent to which these resistances may be modified by laying the outer rail of the curve higher than the inner. He assigns a formula for the determination of the height which must be given to the outer rail, in order to remove as far as possible all retardation from these causes; which formula is a function of the speed of the train, the radius of the curve, and the distance between the rails.

In the latter part of the paper, the author investigates the method of estimating the actual amount of mechanical power necessary to work a railway, the longitudinal section and ground-plan of which are given. In the course of this investigation he arrives at several conclusions, which, though unexpected, are such as necessarily arise out of the mechanical conditions of the inquiry. The first of these is, that all straight inclined planes of a less acclivity than the angle of repose, may be mechanically considered equivalent to a level, provided the tractive power is one which is capable of increasing and diminishing its energy, within given limits, without loss of effect. It appears, however, that this condition does not extend to planes of greater acclivities than the angle of repose; because the excess of power required in their ascent is greater than all the power that could be saved in their descent; unless the effect of accelerated motion in giving momentum to the train could properly be taken into account. In practice, however, this acceleration cannot be permitted; and the uniformity of the motion of the trains in descending such acclivities must be preserved by the operation of the break. Such planes are therefore, in practice, always attended with a direct loss of power.

In the investigation of the formulæ expressive of the actual amount of mechanical power absorbed in passing round a curve, it is found that this amount of power is altogether independent of the radius of the curve, and depends only on the value of the angle by which the direction of the line on the ground-plan is changed. This result, which was likewise unexpected, is nevertheless a sufficiently obvious consequence of the mechanical conditions of the question. If a given change of direction in the road be made by a curve of large radius, the length of the curve will be proportionably great; and although the intensity of the resistance to the tractive power, at any point of the curve, will be small in the same proportion as the radius is great, yet the space through which that resistance acts will be great in proportion to the radius: these two effects counteract each other; and the result is, that the total absorption of power is the same. On the other hand, if the turn be made by a curve of short radius, the curve itself will be proportionately short; but the intensity of the resistance will be proportionately great. In this case, a great resistance acts through a short space, and produces an absorption of power to the same extent as before.

In conclusion, the author arrives at one general and comprehensive formula for the actual amount of mechanical power necessary to work the line in both directions; involving terms expressive, *first*, of the ordinary friction of the road; *secondly*, of the effect of inclined planes, or *gradients*, as they have been latterly called; and, *thirdly*, of the effect of curves involving changes of direction of the road, the velocity of the transit, and the distance between the rails; but, for the reason already stated, not comprising the radii of the curves.

Although the radii of the curves do not form a constant element of the estimate of the mechanical power necessary to work the road, nevertheless they are of material consequence, as far as regards the safety of the transit. Although a short curve with a great resistance may be moved over with the same expenditure of mechanical power as a long curve with a long radius, yet, owing to the intensity of the pressure of the flange against the rail, the danger of the trains running off the road is increased: hence, although sharp curves cannot be objected to on the score of loss of power, they are yet highly objectionable on the score of danger.

In the present paper, the author has confined himself to the analytical formulæ expressing various mechanical effects of the most general kind; the coefficients and constants being expressed merely by algebraical symbols: but he states that he has made an extensive series of experiments within the last few years, and has also procured the results of experiments made by others, with a view to determine the mean values of the various constants in the formulæ investigated in this paper. He has also, with the same view, made numerous observations in the ordinary course of transit on railways; and he announces his intention of soon laying before the Society, in another paper, the details of these experiments, and the determination of the mean values of these various constants, without which the present investigation would be attended with little practical knowledge.

A paper was also read, entitled "Register of the State of the Barometer and Thermometer kept at Tunis, during the years 1829, 1830, 1831 and 1832." Presented by Sir Thomas Reade, His Majesty's Agent and Consul General at Tunis. Communicated by P. M. Roget, M.D., Sec. R.S.

The observations here registered are those of the thermometer at 9 A.M., at noon, and at 6 P.M., and the points of the wind, and height of the barometer for each day of the abovementioned years.

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## May 5, 1836.

FRANCIS BAILY, Esq., Vice-President and Treasurer, in the Chair.

Edward Burton, Esq., William Sands Cox, Esq., and Captain Thomas Locke Lewis, R.E., were elected Fellows of the Society.

A paper was in part read, entitled "On the Optical Phenomena of certain Crystals." By Henry Fox Talbot, Esq., F.R.S.

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## May 12, 1836.

The Rev. WILLIAM WHEWELL, M.A., Vice-President, in the Chair.

The reading of a paper, entitled "On the Optical Phenomena of certain Crystals," by Henry Fox Talbot, Esq., F.R.S., was resumed and concluded.

In this memoir the author gives an account of the optical properties of certain minute crystals, obtained by the evaporation of a solution of borax in phosphoric acid, exhibited when they are examined by means of the polarizing microscope. The field of view is then seen covered with minute circular spots, each composed of a close assemblage of delicate acicular crystals, radiating from the centre; together with other circular bodies, in which this disposition is not observable, on account of the close union of the component crystals, which, producing optical contact, gives perfect transparency to the whole mass. When the field of view is rendered dark by the rectangular crossing of the polarizing laminæ, each of these little circles becomes luminous, and exhibits a well-defined dark cross, dividing its area into four equal sectors. These crosses have a similar position in all the circles; and their direction remains unaltered when the crystals are turned round in their own plane, by causing the plate of glass, on which they are placed, to revolve.

On examining the larger circles with a high magnifying power, and under favourable circumstances of illumination, the author observed upon each a series of coloured concentric rings: but the number as well as the colour of these rings varies in different crystals. The innermost ring is deeply coloured, or black; and incloses a central space of white light, which is traversed by the arms of the cross, intersecting in the centre. This part of the cross, which stands within the innermost ring, is beautifully defined, and perfectly black. The whole system of phenomena are exactly analogous to that exhibited by uniaxal crystals; and corresponds still more closely with those discovered by Sir David Brewster in spheres of glass, the density of which had been rendered variable from the centre to the surface by immersion in heated oil; excepting that the miscroscopic crystals here described are possessed of a far more intense polarizing energy. The author thinks it probable that the phenomena are in both cases produced by similar conditions of density; which, in a circular mass formed by the aggregation of needle-shaped crystals radiating from a common centre, it is natural to suppose would rapidly increase from the circumference to the centre. By watching the progress of crystallization he ascertained that this was, in fact, the mode in which the crystals are constructed: for they frequently appeared, at first, in the form of lengthened prisms, which subdivided themselves at both ends into an immense multitude of divergent fibres, like those of a brush; apparently repelling each other as they extended in length, and occupying spaces corresponding to two opposite sectors of a circle; until, by spreading still farther in breadth, their edges united, and filled the whole of a circular area. In all the stages of this process, the formation of the black cross may be seen to keep pace with the developement of the crystal, until perfectly displayed on the completion of the crystalline structure. The author notices the analogy which this structure presents with that of the crystalline lens of the cod fish, as has been lately described by Sir David Brewster; and also the remarkable correspondence existing between the optical properties resulting from this structure, and the phenomena of the circular polarization of fluids, which have been accounted for by the existence of molecules of a structure nearly similar.

The author proceeds to examine the action of these crystals in common, or unpolarized light; and concludes from his inquiries that each of their diameters polarized the light in the plane passing through itself and the direction of the ray; so that the whole emergent light consists of equal portions polarized in every plane, and according to every diameter of the circle. This action is similar to that which would be exerted by an assemblage of an infinite number of pieces of tourmaline cut into the form of infinitely small sectors, in the direction of the axis, and disposed as radii in a circle. The author considers it probable that the tourmaline itself is an aggregate of acicular crystals of this description, disposed in a direction parallel to its axis, and being in optical contact, as well as in perfect mechanical cohesion.

In a postscript to this paper, an account is given of a new species of Dichroism in crystals, to the discovery of which the author was led by applying to them his peculiar method of observation with polarized light. In these experiments the crystals themselves perform the office of the analysing plate, acting on light previously polarized, and transmitted through a plate of mica. Under these circumstances, the crystals of borax, described in the first part of the paper, when examined with a lens of moderate power, appear beautifully coloured with two complementary colours, according to the position of their axes. These experiments tend to confirm the views of Sir David Brewster and others as to the general cause of the dichroism of crystals, which is ascribed to a difference of absorptive energy in different directions with relation to their axes; arising from a difference of elasticity in these respective directions.

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### May 19, 1836.

### RODERICK IMPEY MURCHISON, Esq., Vice-President, in the Chair.

A paper was read, entitled, "On the valuation of the mechanical effect of Gradients on a line of Railroad." By Peter Barlow, Esq., F.R.S.

The exact amount of the influence of ascents and descents occurring in the line of a railway on the motion of a load drawn by a locomotive engine having been differently estimated by different persons, the author was induced to investigate the subject. A few observations are premised on the erroneous assumptions which, he conceives, have in general vitiated the results hitherto deduced. The first of these is that the expenditure of power requisite for motion is equal to the resistance to traction; whereas it must always greatly exceed it. No account, he remarks, has been taken of the pressure of the atmosphere on the piston, which the force of the steam has to overcome before it can be available as a moving power. Another source of error has been that the statical and dynamical effects of friction have been confounded together; whereas they are the same in amount only when the body is put in motion by gravity; but not when it is urged down an inclined plane by an extraneous force. In the latter case these effects are no longer comparable; friction being a force which, in an infinitely small time, is proportional to the velocity, while that of gravity is constant at all velocities; or, in other words, the retardation from friction is proportional to the space described, while that from gravity has reference only to the time of acting, whatever space the body may pass over in that time. It is an error to assume that the mechanical power of the plane is equivalent to a reduction of so much friction; for the friction down the inclined plane is the same as on a horizontal plane of the same length, rejecting the trifling difference of pressure; and the whole retardation in passing over the plane, or the whole force required to overcome it, is the same at all velocities, and by whatever force the motion is produced; but the assisting force from gravity is quite independent of the space or of the velocity.

In the investigations which the author has prosecuted in this paper, he assumes that equal quantities of steam are produced in the same time at all velocities; and he adopts for his other data, those given by Mr. Pambour in his Treatise of Locomotive Engines. He deduces a formula from which, the speed on a level being given, we may compute the relative and absolute times of a train ascending a plane; and consequently also the ratio of the forces expended in the two cases; or the length of an equivalent horizontal plane; that is, of one which will require the same time and power to be passed over by the locomotive engine as the ascending plane.

The next objects of inquiry relate to the descent of trains on an inclined plane, and comprise two cases: the first, that when the power of the engine is continued without abatement; and the second, that when the steam is wholly excluded, and the train is urged in its descent by gravity alone. The author arrives at the conclusions, that in the first of these cases, when the declivity is one in 139, the velocity, on becoming uniform, will be double that in a horizontal plane: and that for a declivity of one in 695, the uniform velocity of descent will be one fifth greater than on the horizontal plane; and this, he observes, is perhaps the greatest additional velocity which it would be prudent to admit. A plane of one in 695 is therefore the steepest declivity that ought to be descended with the steam-valve fully open; all planes with a declivity between this and that of one in 139 require to have the admission of steam regulated so as to modify the speed, and adjust it to considerations of safety; and lastly, all planes of a greater slope than this last require, in descending them, the application of the brake.

A paper was also read, entitled, "On the application of Glass as a substitute for metal balance-springs in Chronometers." By Messrs. Arnold and Dent. Communicated by Francis Beaufort, Esq., Captain R.N., F.R.S., Hydrographer to the Admiralty.

In their endeavours to determine and reduce the errors arising from the expansions of the balance-spring of chronometers consequent on variations of temperature, the authors came to the conclusion that there exist certain physical defects in the substances employed for its construction, beyond the most perfect mechanical form that can be given to it, which interfere with the regularity of its agency: so that however exquisite may be its workmanship, and however complete its power of maintaining a perfect figure when in different degrees of tension, yet the imperfect distribution of its component parts may give rise to great incorrectness in its performance. Hence the balance-spring not only should be made of a substance most highly elastic, but its elasticity should not be given to it by any mechanical or chemical process: as a body in motion, it should be the lightest possible; and, as far as the case admits of, it should be free from atmospheric influence. Glass suggested itself as the only material possessing, in the greatest degree, all these desirable properties. Its fragility, although apparently a great objection to its employment, was found, on trial, to constitute no obstacle whatever; for it was found to possess a greater elastic force than steel itself, and thus to admit of greater amplitude in the arc of vibration.

It was first proposed to ascertain how far a glass balance-spring would sustain low temperatures; and it was found by experiment that it resisted completely the effects of a cold as great as that of + 12° of Fahrenheit's thermometer; thus satisfactorily removing any objection which might be brought against its use from its supposed fragility in these low temperatures. The next object of solicitude was to determine whether it would withstand the shock arising from the discharge of cannon in the vicinity; and its power of resisting concussions of this nature was fully established by experiments made with this view on board H.M.S. Excellent at Portsmouth.

On comparing the performance of glass balance-springs with metallic ones, when the temperatures were raised from 32° to 100°, it was found that while the loss in twenty-four hours in the gold spring was $8^m\ 4^s$, that of steel $6^m\ 25^s$, and that of palladium $2^m\ 31^s$, that of a glass spring was only $40^s$. These differences the authors ascribe principally to the different degrees in which the substances had their elasticity reduced by an increase of temperature. As glass was thus found to suffer a much smaller loss of elasticity by this cause than metals, they proceeded to construct a glass balance suited to the correction of the small error still occasioned by this cause, employing a glass disc for this purpose. The compensation being completed, they next tested the isochronism of the glass spring, and it proved to be as perfect as any metallic spring. Chronometers thus constructed are now in course of trial at the Royal Observatory. In common with all other instruments of the same kind they have shown a disposition to progressive acceleration, the cause of which is but little known, but which appears to be influenced by the action of the air.

The Society then adjourned over the Whitsun week, to meet again on the second of June next.